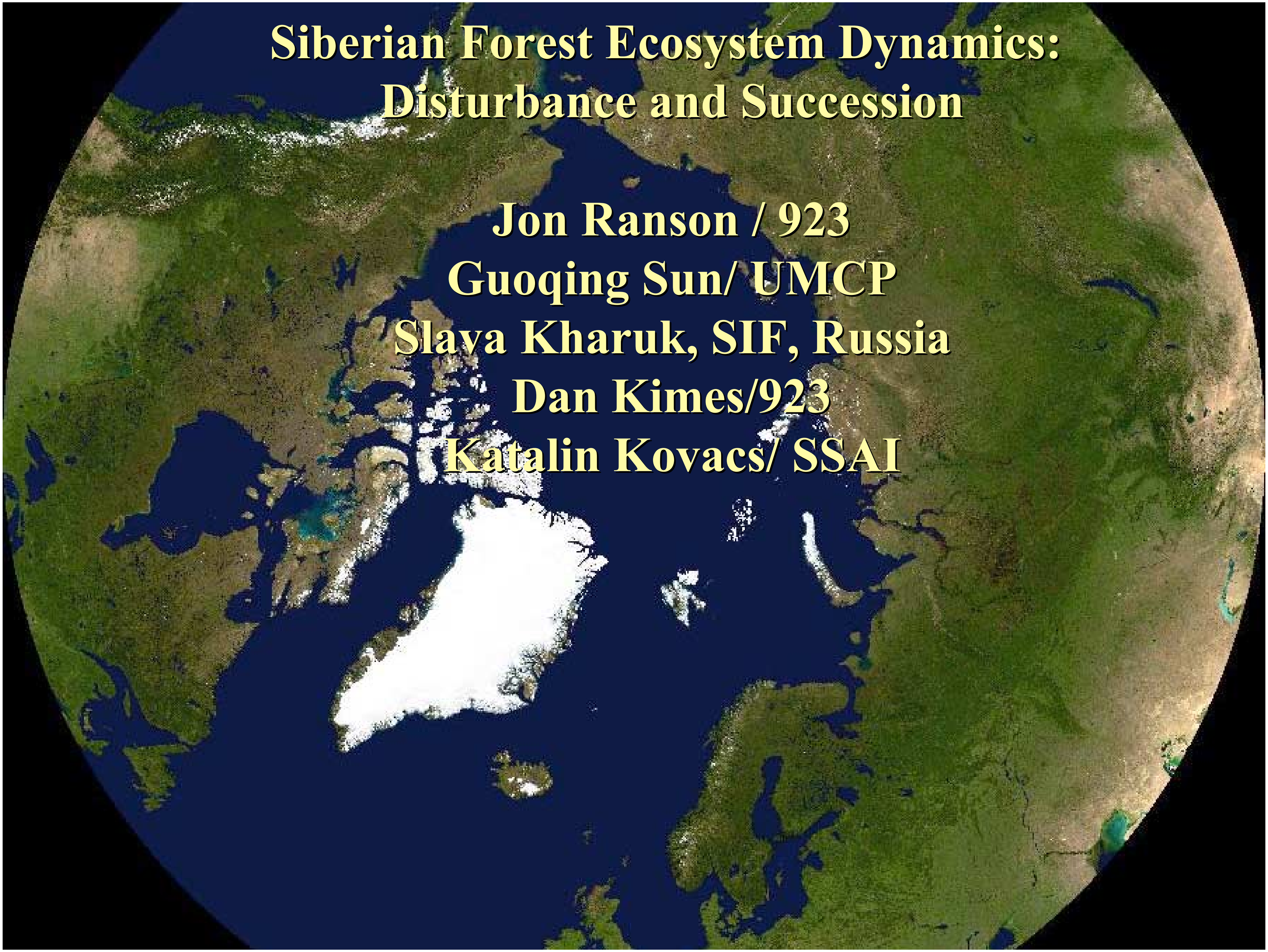

Siberian Forest Ecosystem Dynamics: Disturbance and Succession

Jon Ranson / 923
Guoqing Sun/ UMCP
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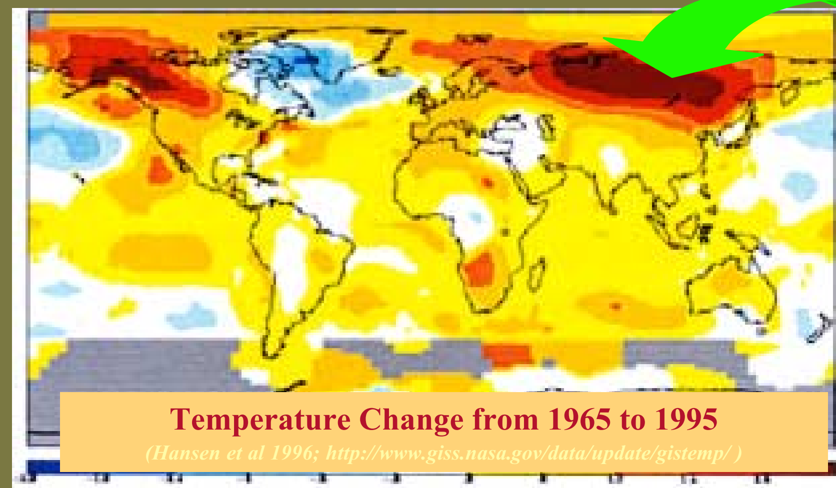
Dan Kimes/923
Katalin Kovacs/ SSAI

Siberian Forest Ecosystem Dynamics: Disturbance and Succession

Understand the dynamics of disturbance and post-disturbance succession in Siberian larch dominated forests.

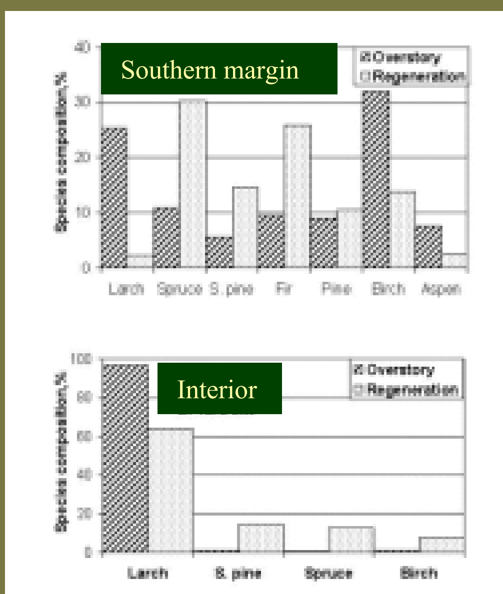
Southern Species appearing in larch forests.



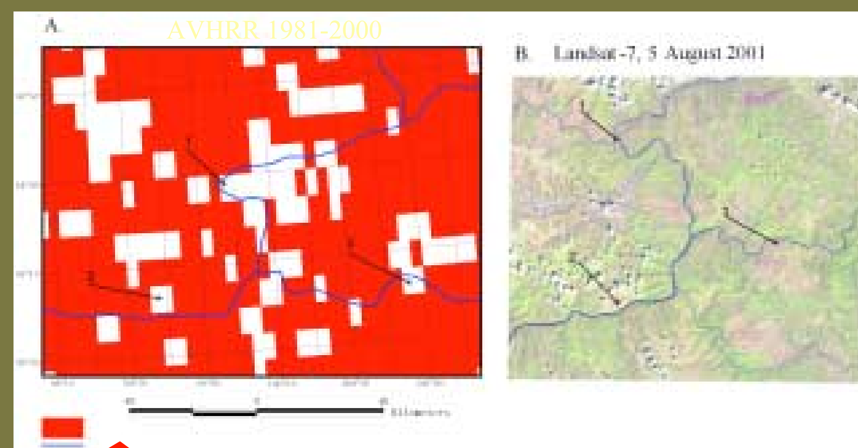
Temperature Change from 1965 to 1995

(Hansen et al 1996; http://www.giss.nasa.gov/data/update/gistemp/)

Central Siberia Study Area



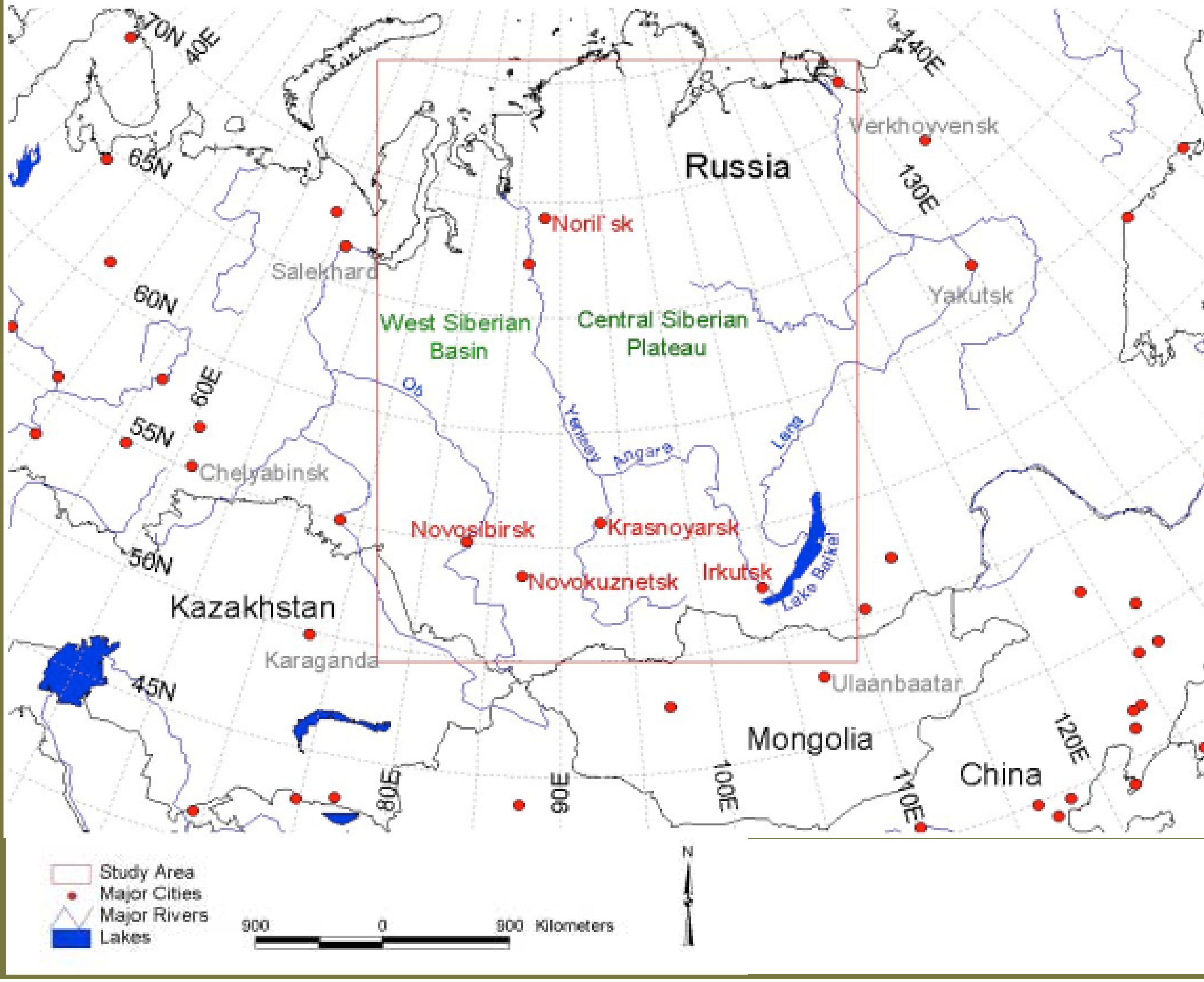
Change in NDVI over 20 years



http://fedwww.gsfc.nasa.gov/SMP/SMP_site/index.html

J. Ranson 923, G. Sun UMCP, V..I. Kharuk SIF

Study Area in Central Siberia



Siberian Forest Ecosystem Dynamics: Disturbance and Succession (NRA-01-OES-06)

Terrestrial ecology analysis of new satellite data and data product continuity to understand ecosystem variability and response to global environmental change.

Purpose: Understand the dynamics of disturbance and post-disturbance succession in Siberian larch dominated forests.

Evidence is growing that changes in environmental conditions in northern regions are changing the forest community structure through changes in disturbance rates, productivity and successional patterns.

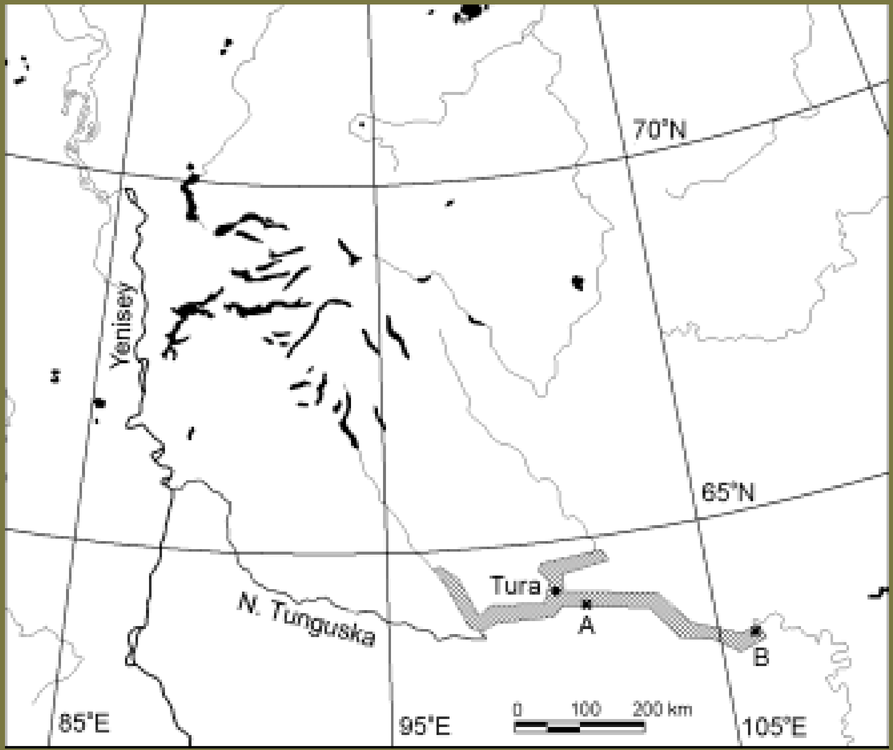
We are evaluating the extent of natural and anthropogenic disturbances and successional dynamics in central Siberia.

Hypothesis: succession will deviate from historical patterns in response to climate changes.

Wildfire Dynamics in Mid-Siberian Larch Dominated Communities

The longterm wildfire dynamics, including fire return interval (FRI), in Siberian larch communities were examined.

A wildfire chronology encompassing the 15th through the 20th centuries was developed from analyzing tree stem fire scars.



Fire scars in Boguchani Area

Ground fire damaged stands Priangar’e – Summer 2000

Effect of Slope on FRI

	FRI ± *s*, yr		Number of Sites	
Aspect	**I.**	**II.**	**I.**	**II.**
SW	**61±8**	**73±8**	**11**	**16**
NE	**86±11**	**105±12**	**13**	**16**
Bogs	**139±17**	**138±18**	**7**	**9**
Plains	**68±14**	**70±13**	**7**	**7**
All TS	**82±7**	**95±7**	**38**	**48**

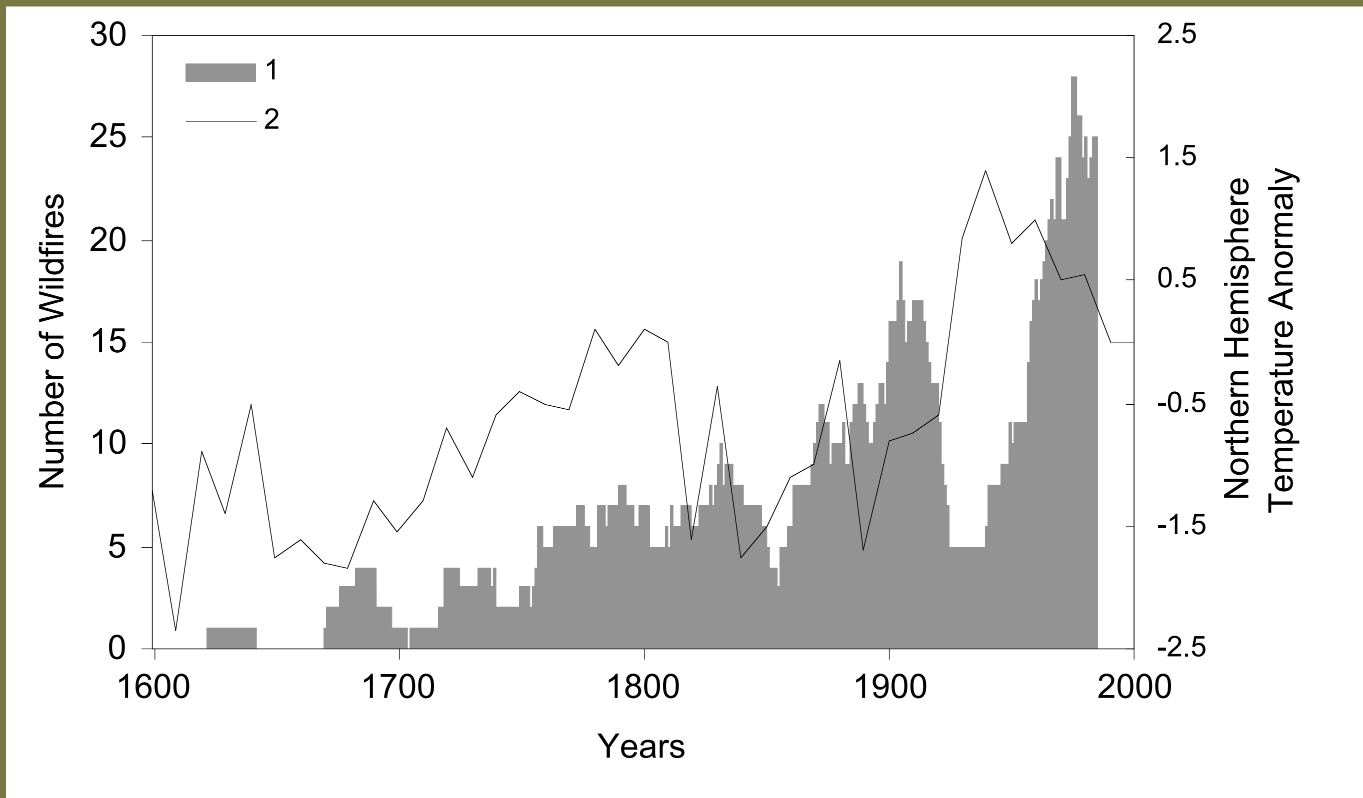
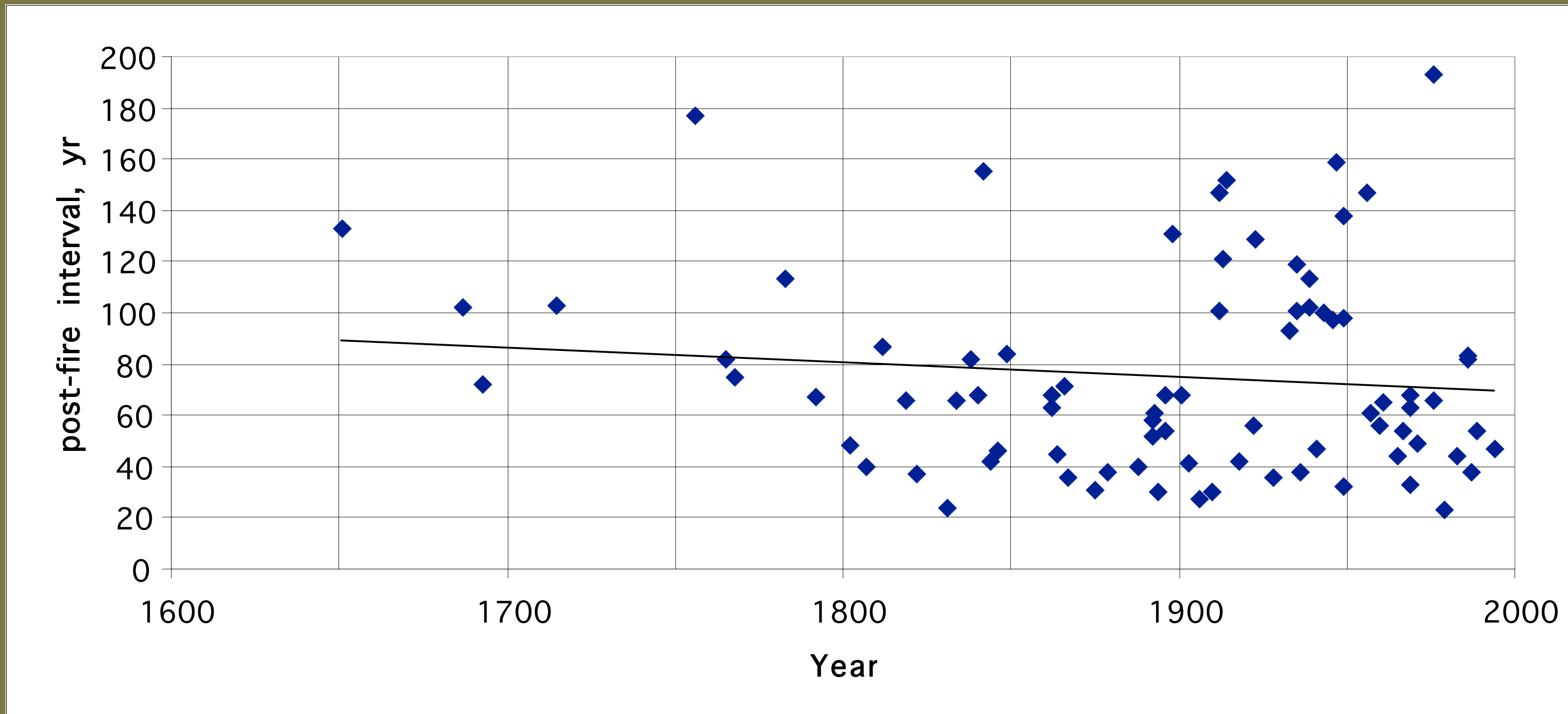


Figure 3. The fire chronology and mean northern hemisphere temperature. 1 – Annual fire number distribution, 2 – mean northern hemisphere temperature (after Bradley and Jones, 1993).



Field measurements acquired during previous NASA projects of fire periodicity within the Yenisey watershed area. Average fire return was estimated to be about 80 years.

The mean values of FRI during the 19th and 20th centuries. s = standard deviation. SW = south-west slopes; NE = north-east slopes; TS = test sites.

	FRI ± *s*, yr	Number of Sites
19th century		
SW	93 ± 29	3
NE	109 ± 25	6
Bogs	125 ± 20	6
All TS	101 ± 12	20
20th century		
SW	58 ± 8	11
NE	74 ± 11	11
Bogs	81 ± 27	4
All TS	65 ± 6	30

Fire Return Interval

The maximum number of annual fires occurred with periods of 36 and 82 years on average.

The temporal trend in the FRI decreased from 101 years in the 19th century to 65 years in the 20th century.

The effect of post-fire forest recovery on depth to permafrost was also estimated. After initial melting from increased local temperatures permafrost depth decreased at a rate of 0.3 cm/yr on average as forest canopies developed.

Paper submitted to J. Wildland Fire Jan. 2004

Using the Terra MODIS Fire Product and vector data to distinguish between natural and anthropogenic fires in the Central Siberian Landscape

The frontier of Earth system science is to:

(1) explore interactions among the major components of the Earth system--continents, oceans, atmosphere, ice, and life,
(2) to distinguish natural from human-induced causes of change, and
(3) to understand and predict the consequences of change.

Source: http://www.earth.nasa.gov/science/

OBJECTIVES

Understand the location, extent and duration of fires with respect to land cover and cultural features.

Investigate the relationship between thermal anomalies, landcover types and human activities

Distinguish between natural and anthropogenic fires

Characterize the severity of natural and anthropogenic fires

Quantify the amount of carbon released by natural and anthropogenic fires

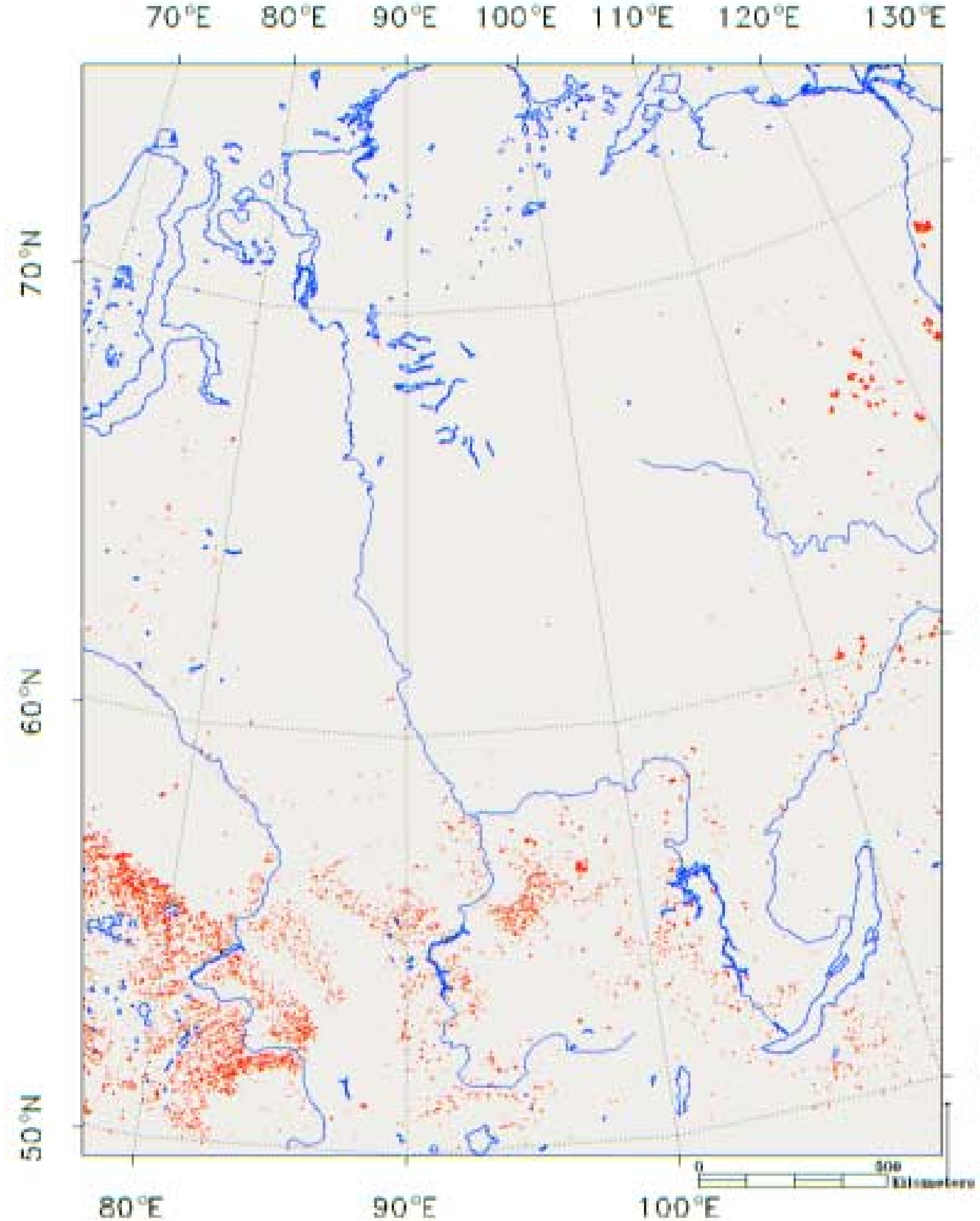
Completed *Planned*

METHODS

- Use Terra MODIS MOD14 data to detect fire locations
- Use Land cover classification derived from our previous work, Terra MODIS MOD12 product and GLA2000 land cover classification.
- Calculate TA persistence from MOD14 to separate Industrial Thermal Anomalies (ITAs) from Land Cover Thermal Anomalies (LCTAs) and verify ITAs using Terra ASTER data.
- Overlay vector data of human activity and calculate the frequency of LCTAs from these anthropogenic features
- Establish area of anthropogenic influence
- Distinguish between natural and anthropogenic fires

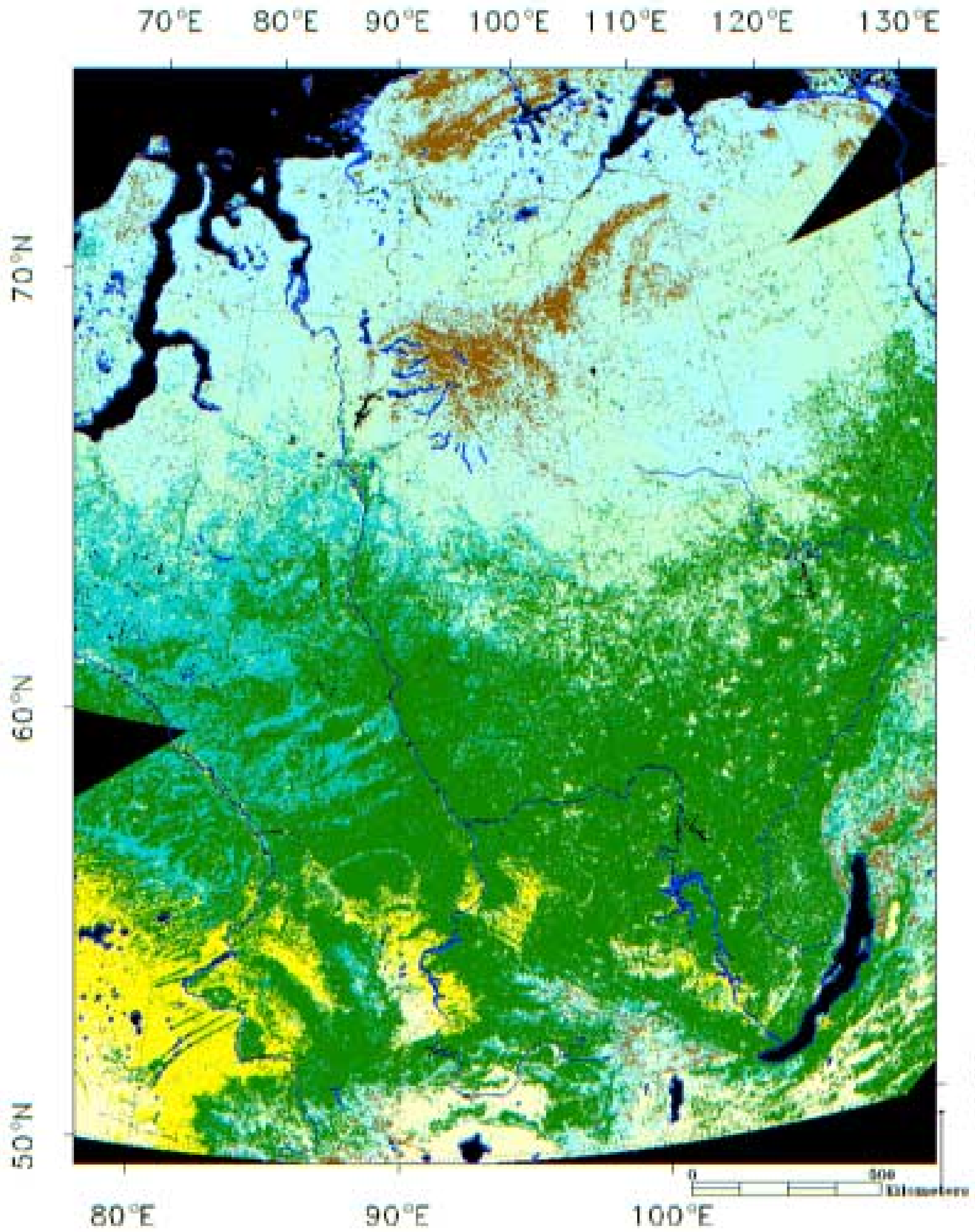
- *Characterize natural and anthropogenic fires using MOD13 NDVI data*

Completed *Planned*



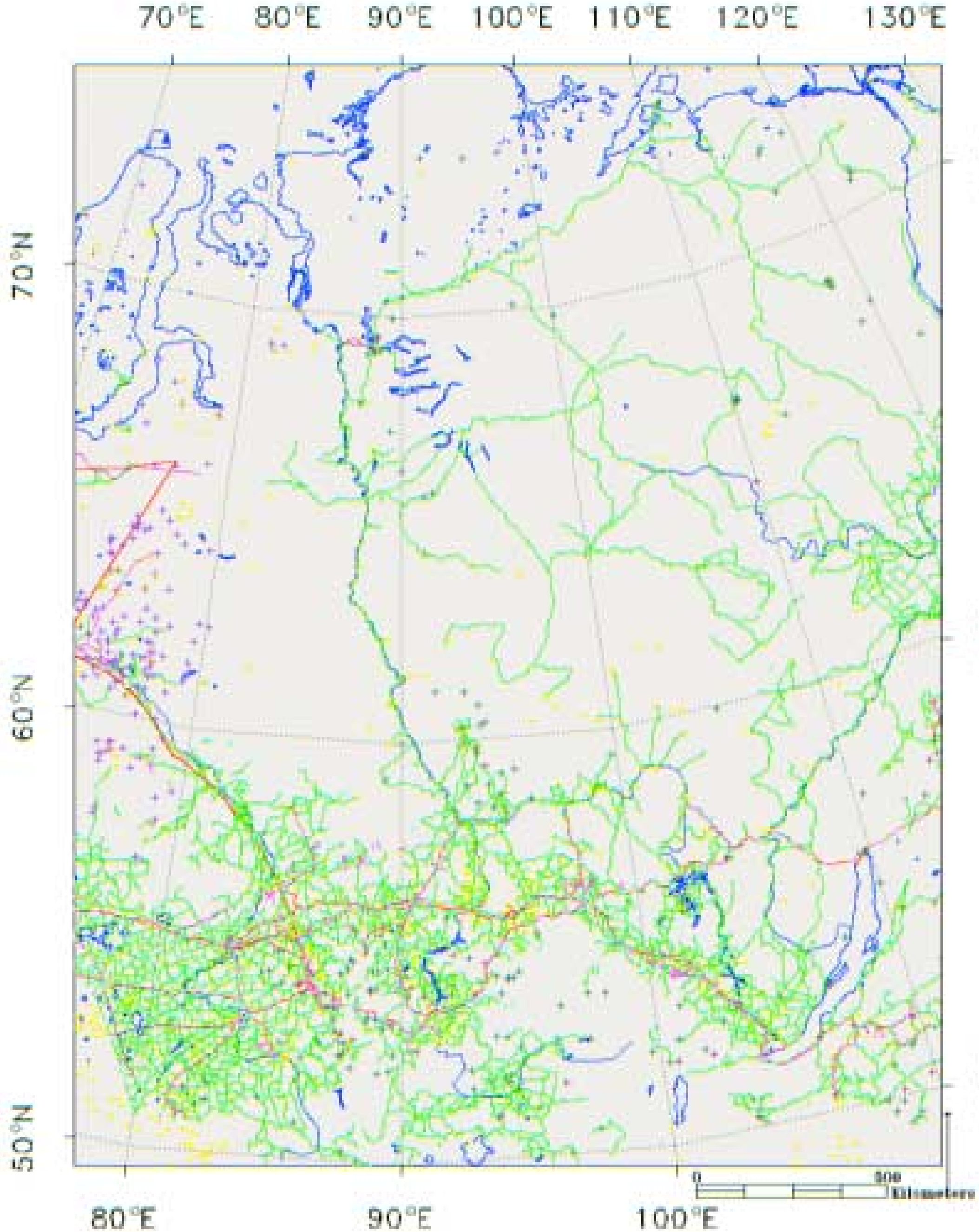
Use Terra MODIS MOD14 data to detect fire locations

March 6, 2001 to November 1, 2001



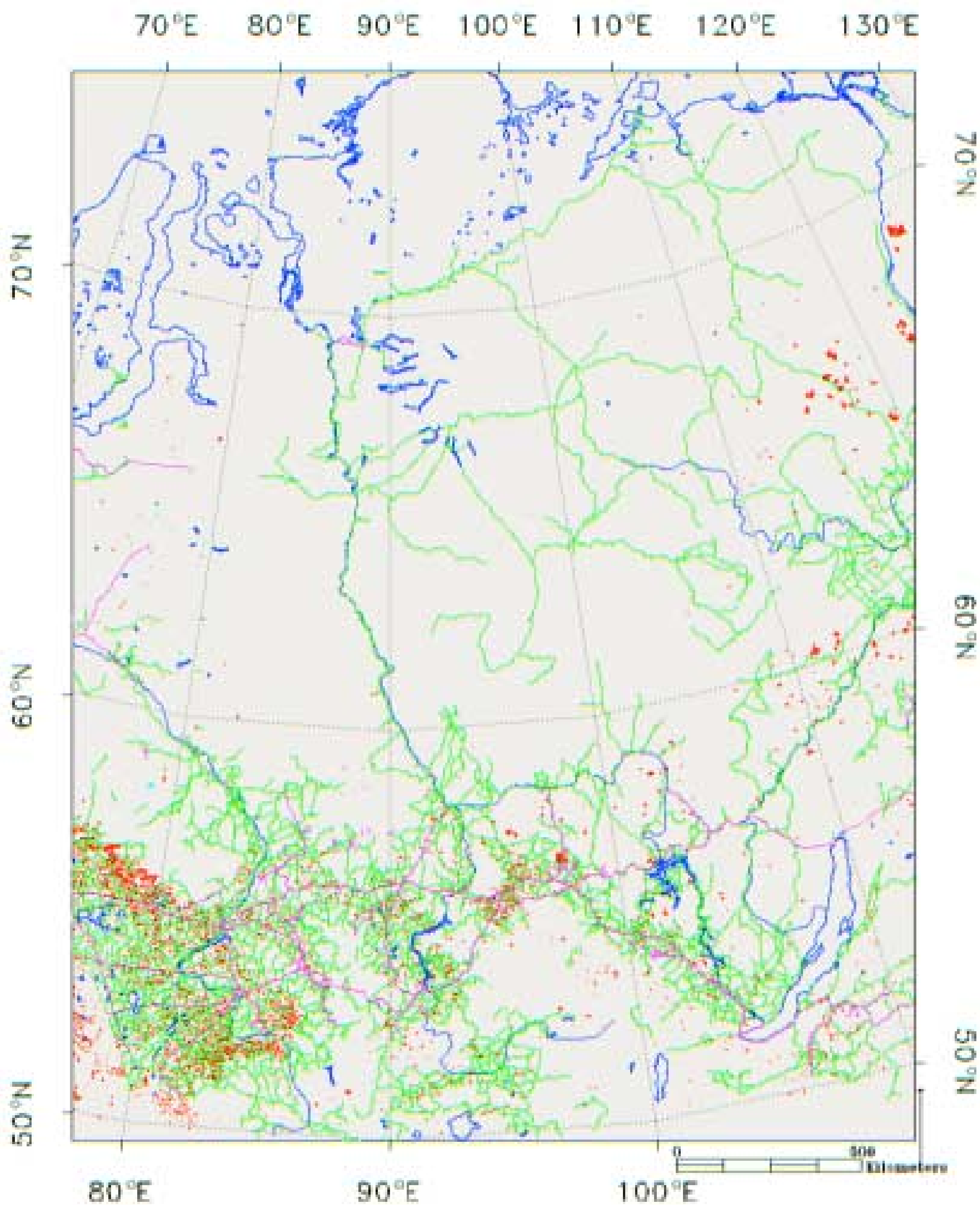
Use Land cover classification derived from our previous work, Terra MODIS MOD12 product and GLA2000 land cover classification.

Different Forest types were merged into one forest class.



Vector data of human activity

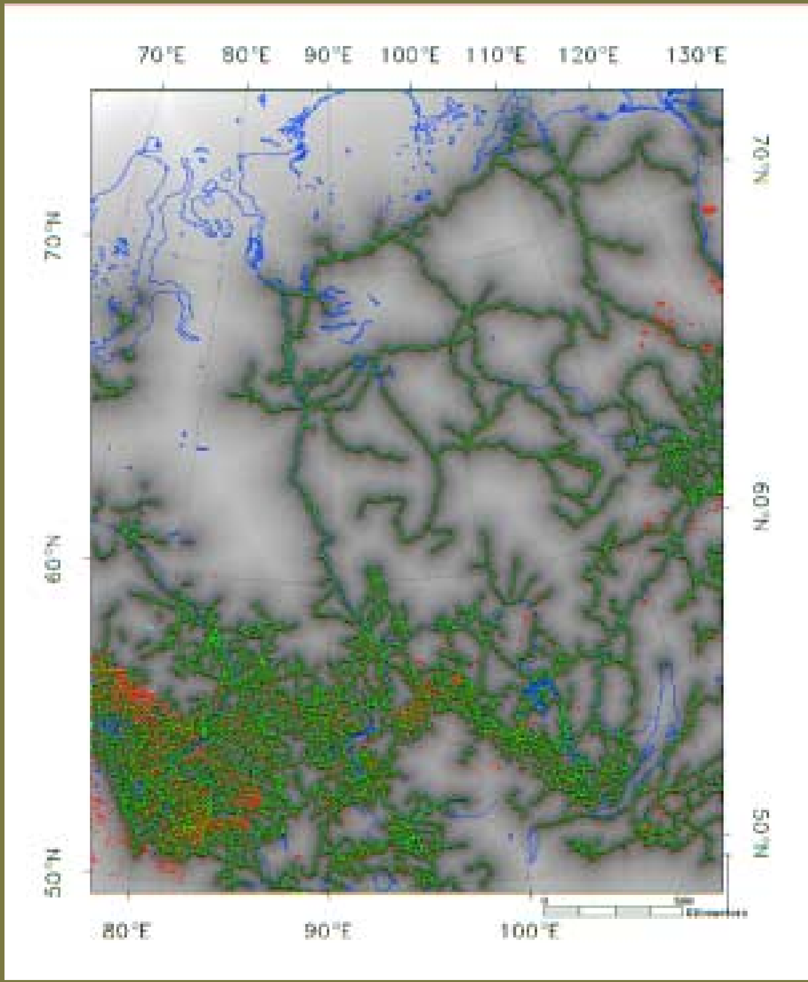
- Navigable Rivers
- Roads
- Railroads
- Human Settlements
- Pipelines
- Industrial Sites
- Saw Mills



Overlay vector data of human activity with thermal Anomalies

- Navigable Rivers
- Roads
- Railroads
- Land Cover TAs
- Industrial TAs

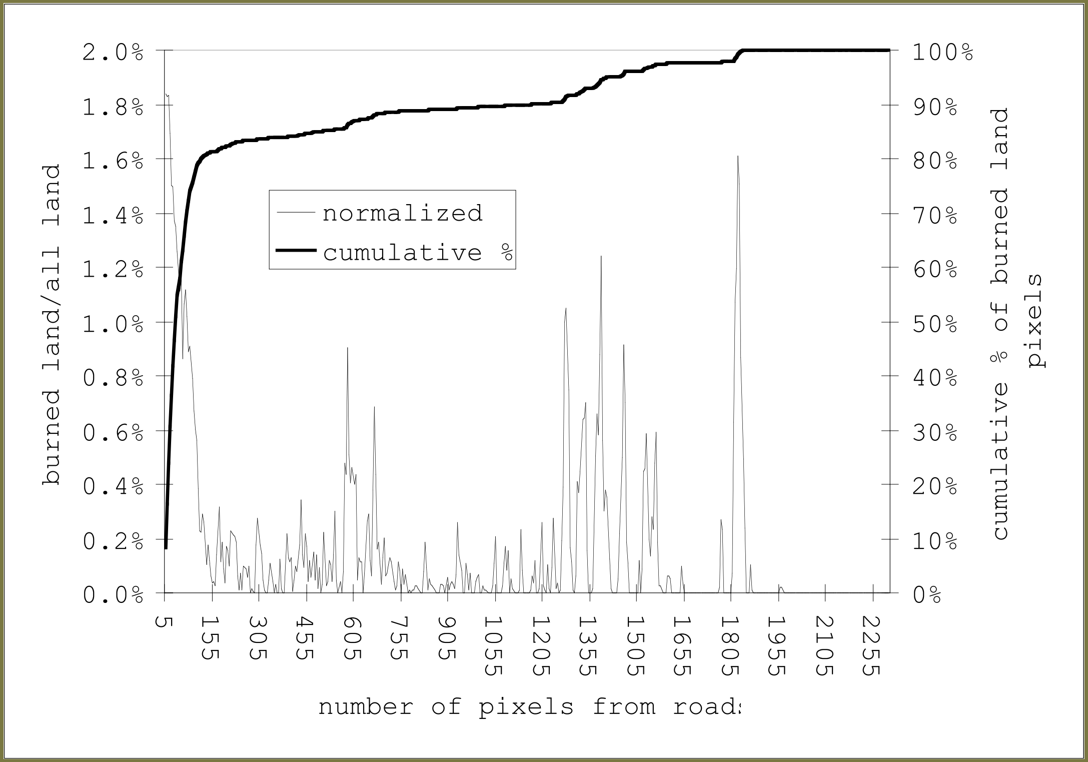
Calculate the frequency of LCTAs from these anthropogenic features

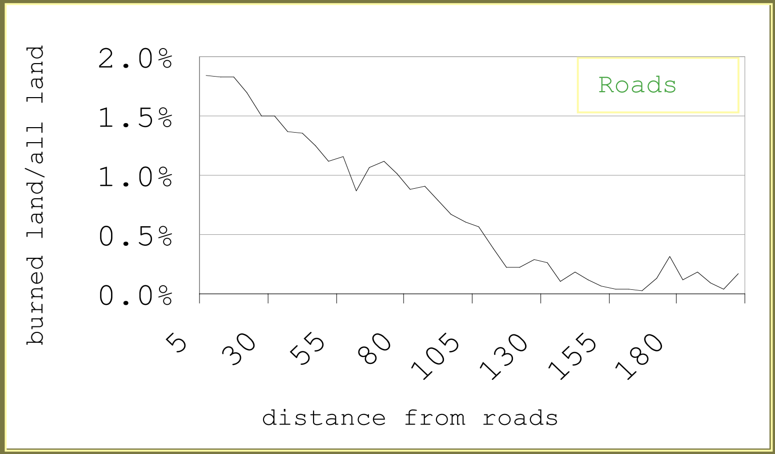


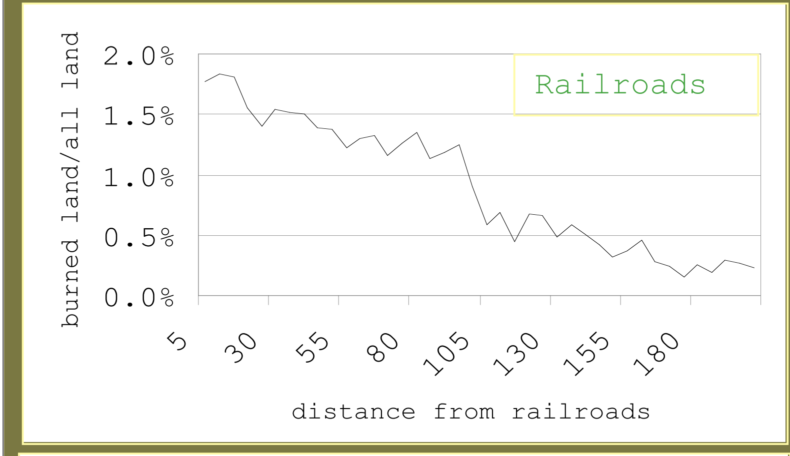
distance(~1km)		pixels		
bin min	bin max	burned	all	burned/unburned
1	5	25	1598	1.56%
6	10	93	7896	1.18%
11	15	56	4890	1.15%
...	...	...	...	...

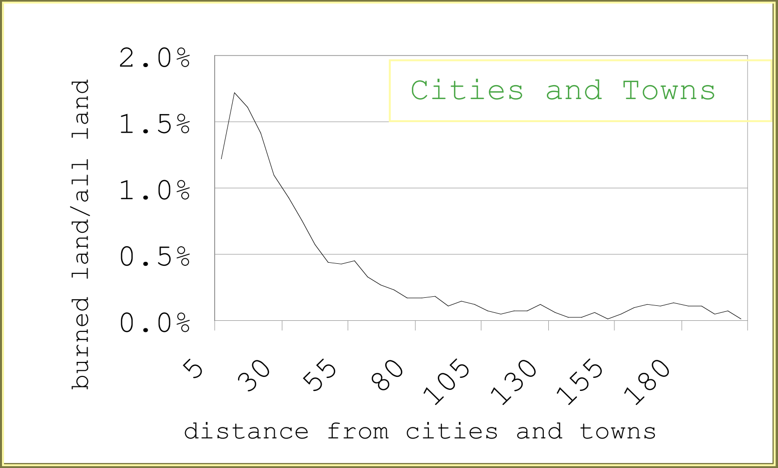
$$\frac{\text{Burned land}_{(\text{bin } i)}}{\text{All land}_{(\text{bin } i)}}$$

Histograms of distance from anthropogenic features and burned land





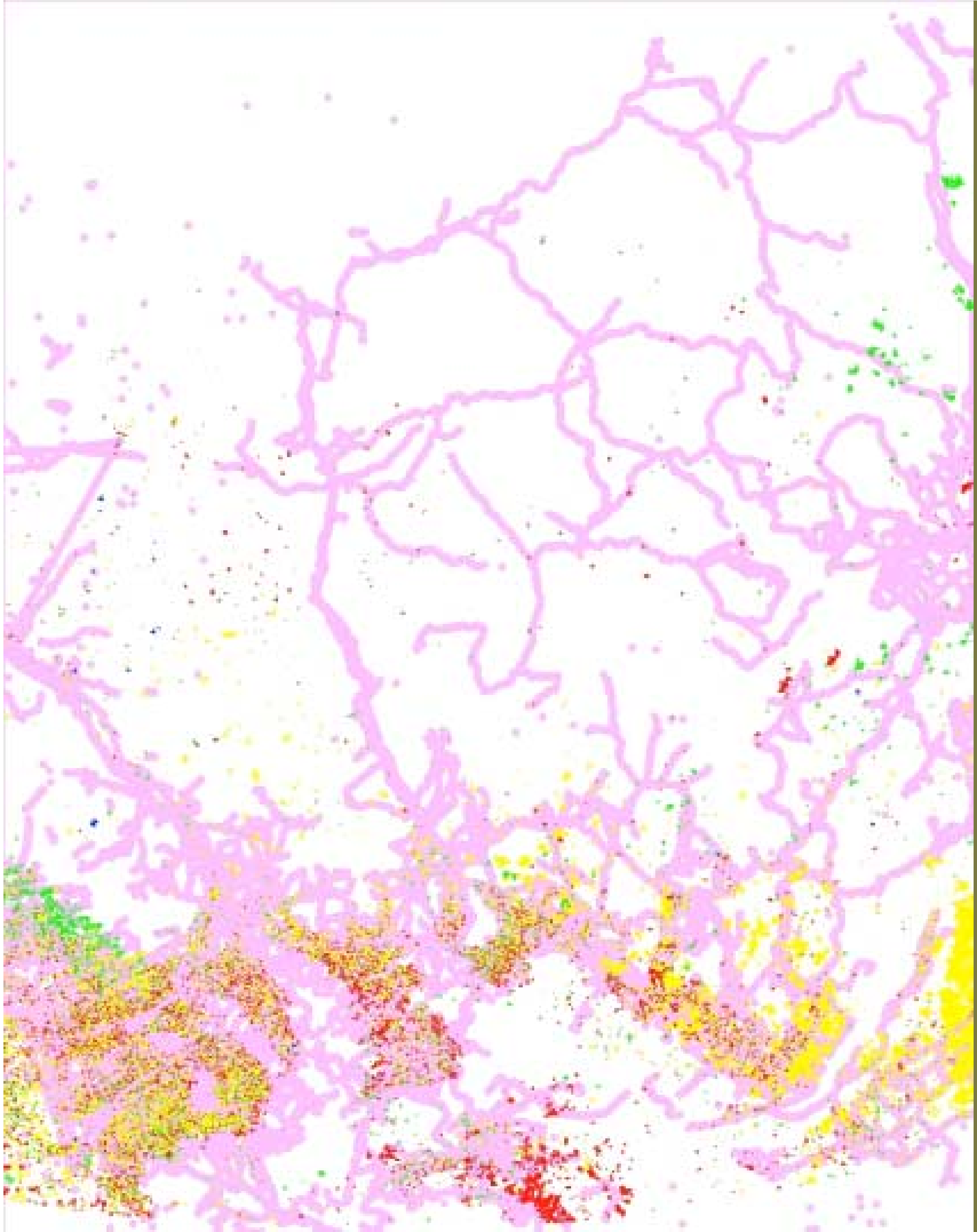




Histogram of the distances between LCTAs and roads in the study area. 82% of all LCTAs are within 200 km from roads.

Correlation matrix between the buffer zones of transportation and cultural features (upper part of table), the land cover classes (middle part of table) and thermal anomalies (lower part of table).

Bands	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 roads	1.00															
2 railroads	0.76	1.00														
3 settlements	0.68	0.53	1.00													
4 mining ind locations	0.78	0.67	0.50	1.00												
5 mineral reserves	0.42	0.17	0.15	0.63	1.00											
6 active oil and gas extr.	-0.12	0.26	0.00	-0.26	-0.49	1.00										
7 oil pipelines	0.91	0.86	0.70	0.65	0.14	0.15	1.00									
8 all rivers	0.30	0.09	0.35	0.26	0.36	-0.14	0.19	1.00								
9 gas flares	-0.23	0.12	-0.09	-0.34	-0.46	0.97	0.01	-0.05	1.00							
10 all Forest	0.52	0.27	0.44	0.43	0.39	-0.13	0.42	0.70	-0.08	1.00						
11 all AG Land	0.97	0.63	0.71	0.73	0.39	-0.22	0.87	0.33	-0.31	0.54	1.00					
12 all Other Land	0.18	0.09	0.18	0.21	0.28	0.01	0.10	0.65	0.09	0.71	0.18	1.00				
13 Forest TA	0.81	0.37	0.69	0.59	0.35	-0.29	0.71	0.41	-0.34	0.58	0.91	0.24	1.00			
14 AGTA	0.95	0.60	0.72	0.72	0.40	-0.25	0.85	0.31	-0.35	0.53	0.99	0.17	0.93	1.00		
15 Other TA	0.67	0.33	0.66	0.56	0.36	-0.25	0.58	0.47	-0.27	0.58	0.77	0.34	0.89	0.80	1.00	
16 ITA	0.56	0.76	0.47	0.45	-0.02	0.47	0.70	0.19	0.40	0.37	0.52	0.25	0.37	0.49	0.34	1.00



10 km buffer zone around anthropogenic vectors and MOD14 fires

Area within 10 km from roads, rail roads, towns, mining industry locations, oil and gas pipelines and navigable rivers

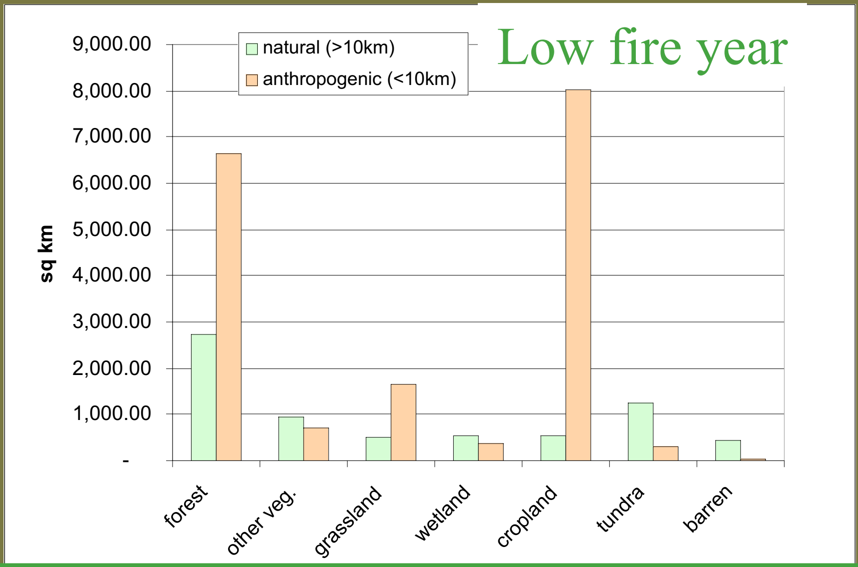
2001 LCTAs

2002 LCTAs

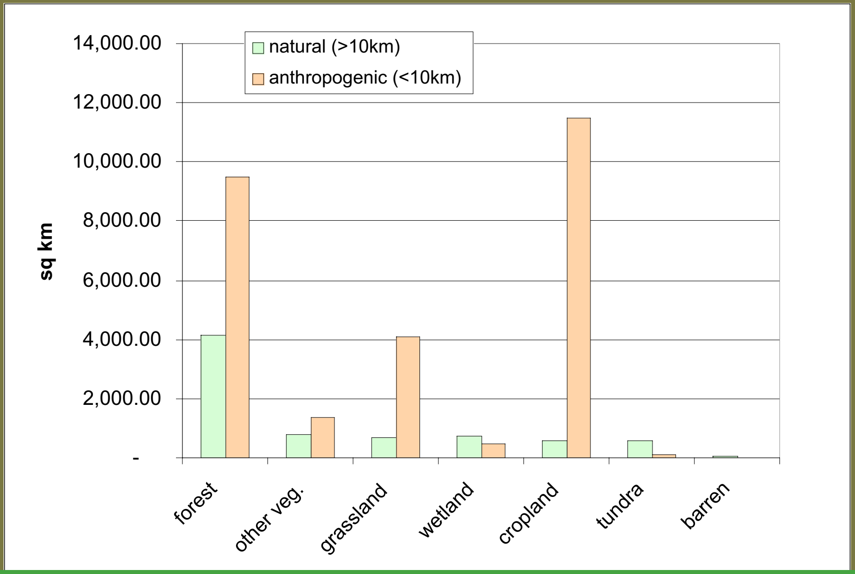
2003 LCTAs

3 year ITAs

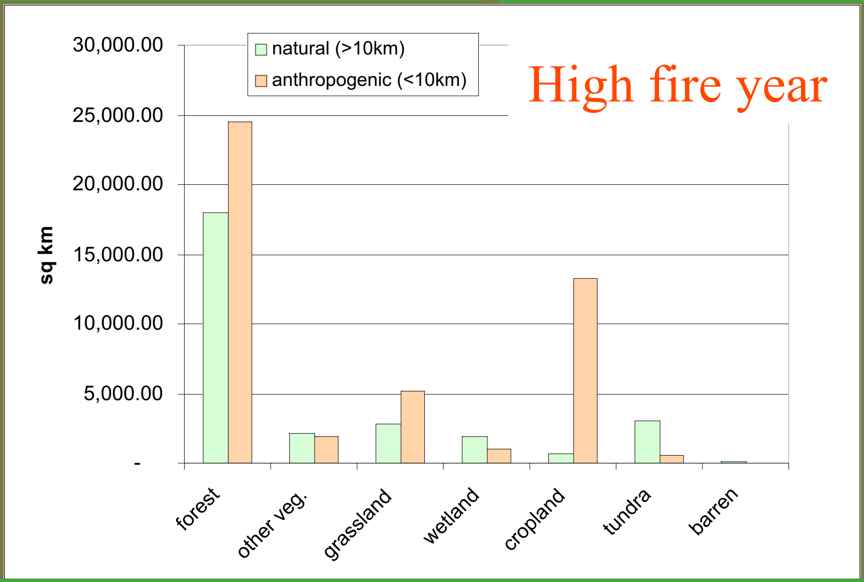
Distinguish natural from human-induced causes of change: 2001 – 2003 MOD14 Thermal Anomalies over central Siberia



70% of all forest fires had an anthropogenic origin in 2001



67 % of all forest fires had an anthropogenic origin in 2002



57 % of all forest fires had an anthropogenic origin in 2002

How does the Earth system respond to natural and human-induced changes?

ΔNDVI shows the change in a burned pixels due to the disturbance and removes the effects of phenology. This assumes that the surrounding forests were similar in NDVI to the burned pixel prior to disturbance.

dNDVI= (NDVIt2-NDVIt0)/NDVIt0 [Eq.1]

where NDVI = (NIR+Red)/(NIR-Red)

NDVIt0 = NDVI value for the 16-day period before the fire

NDVIt2 = NDVI value for the 16-day period after the fire

dNDVIbf = (NDVIt2bf-NDVIt0bf)/NDVIt0bf [Eq.2]

dNDVIsf = (NDVIt2sf-NDVIt0sf)/NDVIt0sf [Eq.3]

where bf = burned forest

sf = surrounding non-burned forest

ΔNDVI = dNDVIbf – dNDVIsf [Eq.4]

EVIDENCE OF CLIMATE-DRIVEN “SOUTHERN SPECIES,, INVASION INTO LARCH-DOMINATED COMMUNITIES

One of the principal expected responses of the larch-dominated communities (LDC) to climate trend is the invasion of the “southern,, species (Siberian pine, pine, spruce, fir, birch).

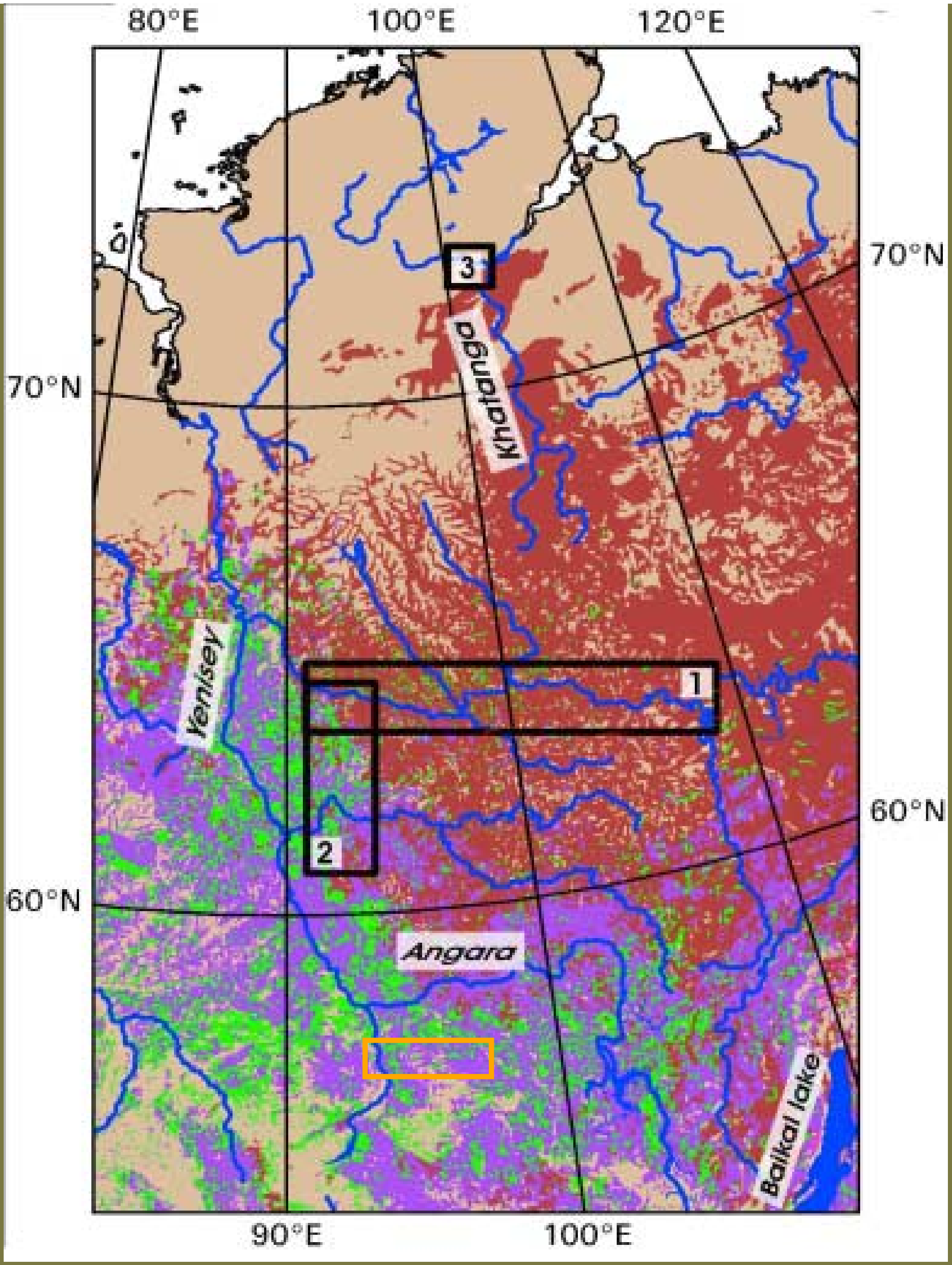
The purpose of this study is to detect this phenomenon based on remotely sensed and on-ground data. The analyzed area consists of two transects. south-north (SN, 60° - 65° N.L., 420 km length) west-east (WE) transect (88°- 107° E.L., 1050 km length)

MODIS, Landsat, forest inventory and SPOT VEGETATION-derived maps were analyzed. On-ground studies were made in 2001-03 (80 test sites (TS) along WE and 58 test sites along SN transects).

Ground measurements included: GPS location, topography (elevation, azimuth, slope), forest inventory data, disturbance type (wildfires, logging), regeneration, ground cover, soil type, depth of permafrost thawing.

150 km wide transects

Ground surveys in 2002



Coefficient of reproduction

$$K_i = (n_i - N_i)/(n_i + N_i),$$

where n_i is proportion of *i-th* species in regeneration, N_i proportion of the *i-th* species in overstory.

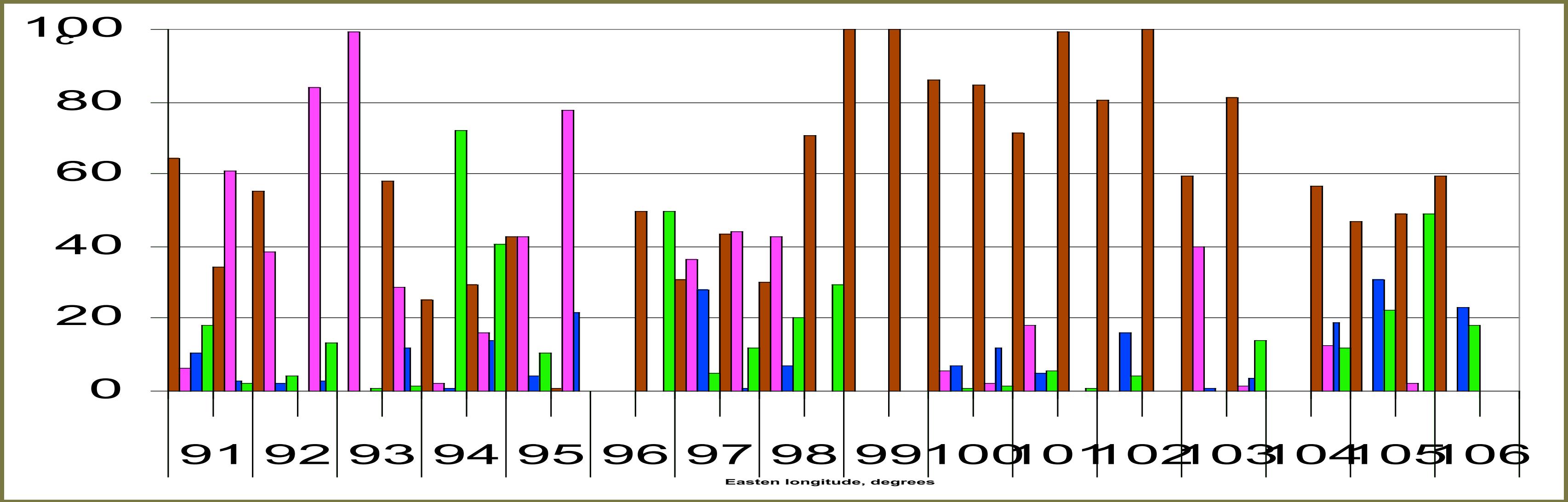
An indicator of possible climate-driven species change

The overstory data were taken from remotely sensed and ground surveys: the proportion of larch, Siberian pine, spruce, fir, pine, and birch along transects were generated.

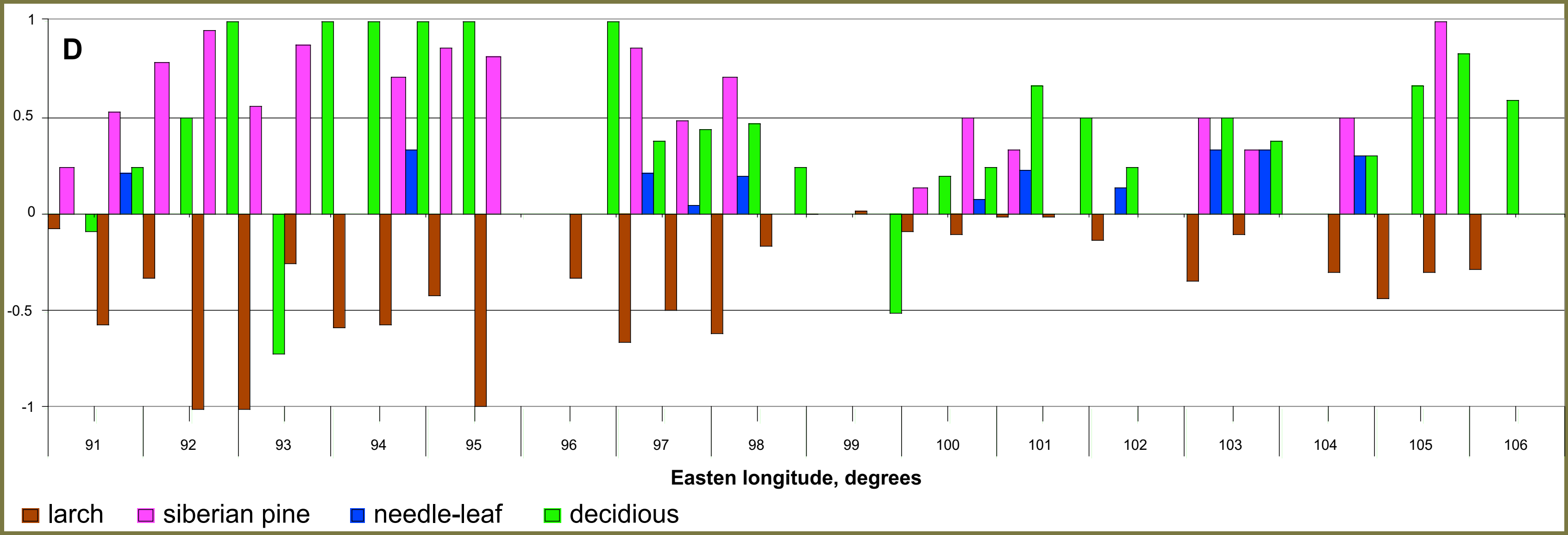
The K_i values along both transects will be analyzed along with climate trends based on the local meteorology data.

Species distribution A) forest inventory map 1990 B) ground data

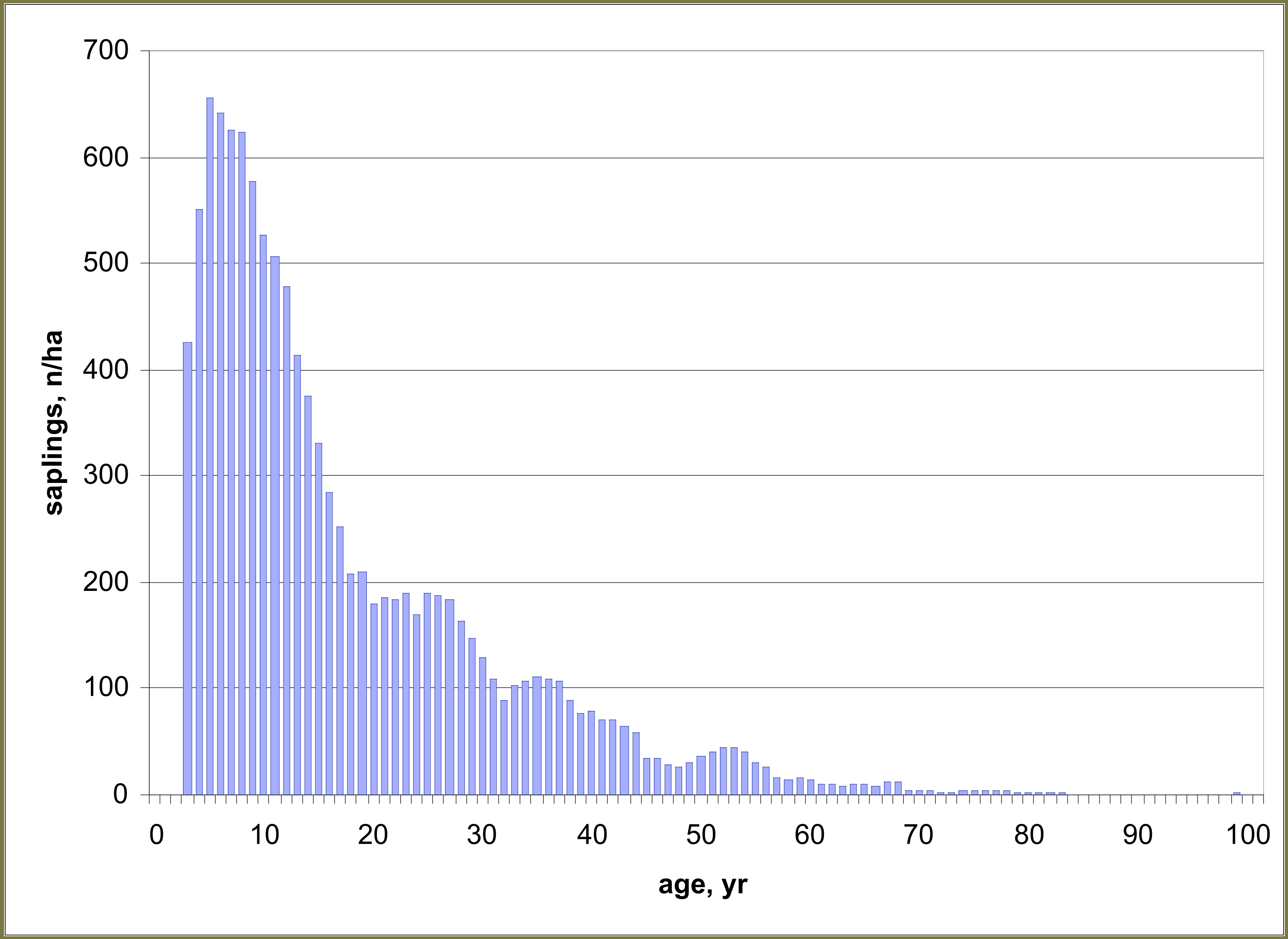
Regeneration



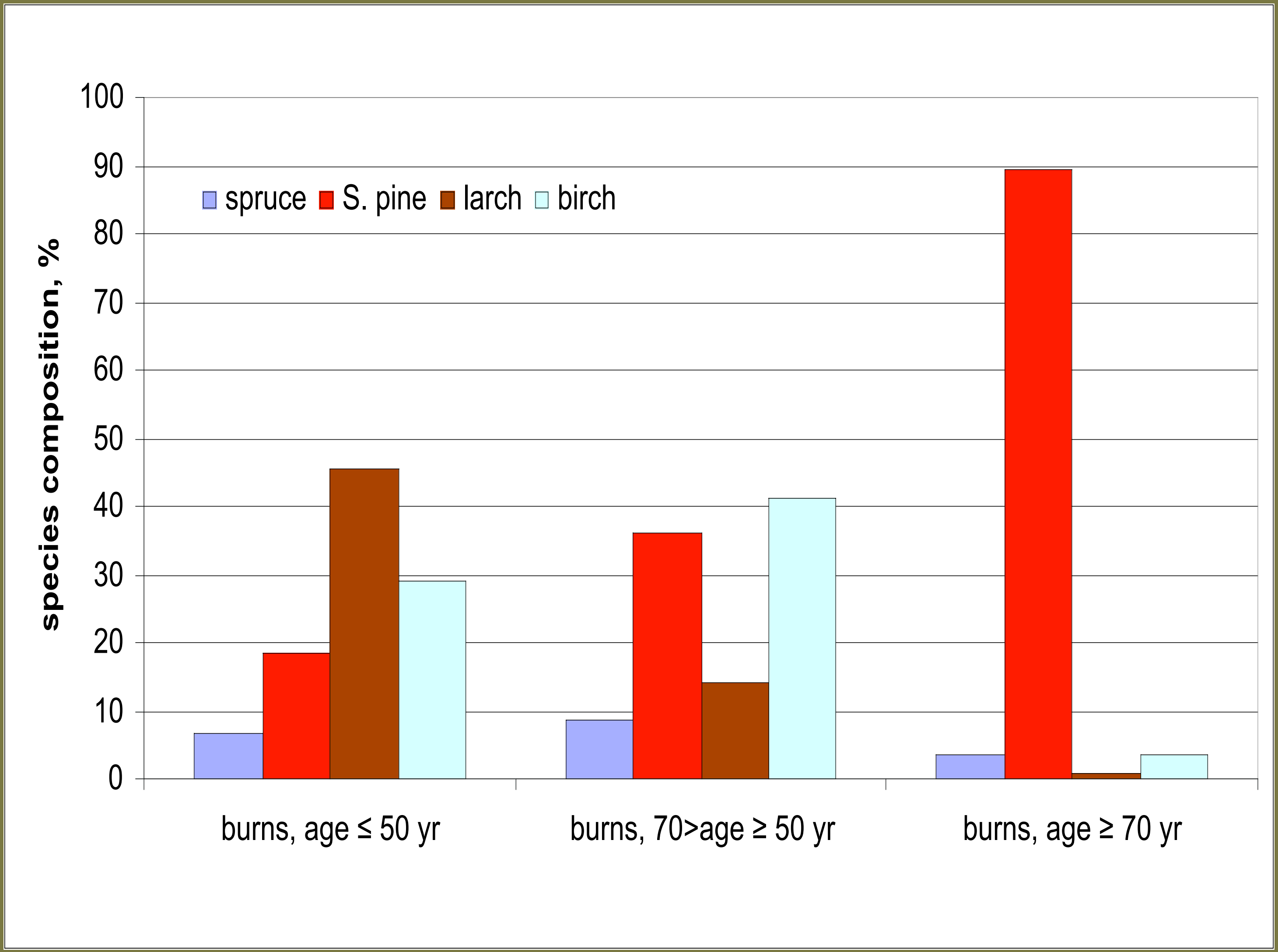
Reproduction Coefficient, K



Age structure of “southern species,,



S. pine regeneration is more abundant in old burns in comparison with fresh ones, whereas larch and deciduous (birch, in the western part of the transect) preferably occupy fresh fire scars.



K_i of “southern species„ is high for areas where their presence should be negligible.

- However, K_i of larch is low even in the middle of LDC.
- Regeneration age structure of the “southern species„ showed that seedlings appeared mainly during last three decades, corresponding to a period of observed warming.
- S. pine regeneration is more abundant in old burns in comparison with fresh ones, whereas larch and deciduous (birch, in the western part of the transect) preferably occupies fresh fire scars.
- Fire return interval in the 20th century decreased in comparison with 19th century
- This may interfere with the “southern species„ invasion into LDC.

Boreal Zone Forest Type and Biomass from Fused Data Sets (NRA-03-OES-02)

Ojective: Improve forest identification and biomass estimation by combining MODIS, MISR and GLAS data sets to utilize horizontal and vertical structure information.

Methods: Select regions in Central Siberia to develop techniques, use Terra and ICESAT data to classify forest and estimate biomass based on field studies. Use other field measurements to validate.

*Then apply to circumpolar boreal forest.

Expected results
Improved forest classification of boreal zone, improved biomass estimates using vertical dimension. Improved disturbance recognition and monitoring.